THRUST BALANCING DEVICE FOR CRYOGENIC FLUID MACHINERY

Applicant claims the benefit of U.S. Provisional Application No. 60/446,460, filed February 10, 2003.

BACKGROUND OF THE INVENTION

This invention relates in general to means and methods for balancing the thrust felt by pumps and turbine generators operating in a cryogenic environment, and in particular to a novel improvement in a thrust balancing configuration to enhance the rotordynamic behavior of vertical cryogenic pumps and turbine generators.

The LNG (liquid nitrogen gas) production plants currently in the design stages are utilizing economy of scale to increase production with lower capital costs, which has the effect of increasing the power ratings of the critical rotating equipment being supplied. As the power requirements increase with the demand for the next generation of liquefaction plants, the generator size must increase physically. As the generator is the dominant component in terms of rotordynamic stability, the increased size has negative ramifications to the machine reliability. For example, higher power ratings of variable speed hydraulic turbine generators implicitly require larger physical sizes, but the possible loss of generator load demands critical speed separation below continuous speed and above maximum "breakaway" speed. Furthermore, in the design of cryogenic turbine generators and pumps, there limitations on bearing size, shaft diameter and overall diameter of machines of this type. This invention presents a solution for increasing the generator size, and power rating, while still maintaining acceptable rotordynamic characteristics.

For vertical cryogenic turbine generators, power increases of up to 10% can be achieved by reducing the span between the main bearings which offsets the reduction in

the critical speed resulting from the increased generator size. However this is not readily accomplished in machines having ball bearings which are cooled and lubricated by the product fluid. This is because the upper main bearing needs to be located outside of the generator end turns to avoid any possible electrical effects associated from the variable speed electrical control system of the generator, and the lower bearing is typically integral to a thrust balancing system which is necessary due to the low viscosity of liquefied hydrocarbon gases. The thrust balancing system is necessary to eliminate the thrust generated by the hydraulic components against the bearings in order to achieve adequate running time between overhauls. The TEMs (Thrust Equalizing Mechanism) mechanisms incorporated in machinery designed by Ebara International Corporation, Sparks, Nevada, are good examples of such thrust balancing mechanisms which employ a combination of fixed and variable orifices, but there are limitations with regards to location, length and resultant variable orifice gap size. This invention provides a way for the lower bearing to be disposed closer to the upper bearing, thereby reducing the gap therebetween, without interfering with the thrust balancing mechanism.

Other advantages and attributes of this invention will be readily discernable upon a reading of the text hereinafter.

SUMMARY OF THE INVENTION

An object of this invention is to provide a way for the lower bearing to be disposed closer to the upper bearing, thereby reducing the gap therebetween, without interfering with the functioning of a thrust balancing mechanism.

A further object of this invention is to provide an improvement for reducing the span between main bearings to offset the reduction in critical speed resulting from increased machinery size.

These objects, and other objects expressed or implied in this document, are accomplished by a novel improvement for a turbine generator or pump having main bearings separated by a span of shaft and a thrust equalizing mechanism adjacent one of said main bearings, the improvement comprising a stationary spacer interposed between the thrust equalizing mechanism and its adjacent main bearing to reduce the span between said main bearings. Preferably the spacer is composed of material that shrinks less than the shaft of the generator, and the height of the spacer, i.e., the spacing dimension, is selected according to desired thrust equalizing mechanism operating parameters over a temperature range. For a turbine generator or pump having main bearings separated by a span of shaft and a thrust equalizing mechanism which includes a stationary thrust plate adjacent one of the main bearings and a variable orifice defined between the thrust plate and a throttle plate affixed to the shaft, an improvement comprising a stationary length compensator interposed between the thrust plate and its adjacent main bearing to space said adjacent main bearing from the thrust plate in order to reduce the span between said main bearings. Preferably the length compensator is composed of material that shrinks less than the shaft of the generator, and the heights of the thrust plate and the length compensator are selected to produce a desired variable orifice over a range of operating temperatures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a partial cross-sectional view of a prior art pump/turbine generator in the vicinity of the lower main bearing and encompassing the runner/impeller.

Figure 2 is a more detailed view cut from Figure 1 focusing on the thrust plate-throttle ring interface.

Figure 3 is a partial cross-sectional view of a pump/turbine generator according to this invention focused in the vicinity of the lower main bearing and encompassing the runner/impeller.

Figure 4 is a more detailed view cut from Figure 3 focusing on the thrust plate-throttle ring interface.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figs. 1 and 2, a prior art machine with a conventional thrust equalizing mechanism is illustrated to have a housing 2, a shaft 4, a lower bearing 6, a stationary thrust plate 8, a throttle ring 10 affixed to the shaft, a runner 12, a gap 14 above the lower bearing which allows the shaft (and the bearing and throttle ring) to rise in response to any unbalance thrust from below, a fixed orifice 16 which communicates product fluid to a chamber 18 disposed above the throttle ring, a variable orifice 20 defined between thrust plate and the throttle ring, an upper wearing ring 22, and a lower wearing ring 24. The operation of the thrust equalizing mechanism is simple. The upper wearing ring 22 is larger in diameter than the lower wearing ring 24 resulting in a net resultant force in the upper direction. Due to this upward force, the shaft 4, and all its rotating components move upward, the upward movement of the throttle ring 10 reducing the variable orifice 20 between it and the thrust plate 8, thus restricting the wearing ring leakage flow and causing the pressure in the chamber 18 to increase. Due to increased pressure in the chamber 18, the thrust is reversed and now acts in a downward direction. This causes the rotating assembly to move downward, thereby opening the variable orifice allowing the pressure in the chamber 18 to decrease. The operation vacillates back and forth automatically adjusting the pressure in chamber 18 sufficient to offset the upward thrust. Continuous self-adjustment allows the product-lubricated ball bearing 6 to

operate essentially at zero thrust load over the entire usable capacity range. This feature substantially increases the reliability of the bearings, and reduces equipment maintenance requirements.

As explained above, it is desirable to reduce the span between the main bearings in order to offset the reduction in the critical speed resulting from an increased generator size. However, relocating the lower bearing 6 by the requisite amount would entail a dramatic increase in the length of the thrust balancing device, and the resultant differential shrink between the thrust plate 8 material and the shaft 4 would cause the variable orifice gap 20 to increase to such a degree that the thrust equalizing device would be rendered inoperable. Referring to Figs. 3 and 4, the solution to this problem is to integrate another component, a length compensator 26, within the device composed of a material that shrinks less than the shaft. The length compensator 26 is interposed between the bearing block and the thrust plate to space the bearing higher, i.e. closer to the upper main bearing. According to this invention, the individual heights of the thrust plate and length compensator are selected to produce the desired variable orifice gap 20 at the actual operating temperature that will result in the most effective thrust balancing and highest machine efficiency.

The foregoing description and drawings were given for illustrative purposes only, it being understood that the invention is not limited to the embodiments disclosed, but is intended to embrace any and all alternatives, equivalents, modifications and rearrangements of elements falling within the reasonable scope of the claims which follow herein.

I CLAIM: